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1 Providing evidence to support the development of whole grain dietary recommendations in
2 the United Kingdom.

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Abstract

Observational evidence suggests that increased whole grain (WG) intake reduces the risks of many non-communicable diseases, such as cardio-vascular disease, type 2 diabetes, obesity and certain cancers. More recently, studies have shown that WG intake lowers all-cause and cause-specific mortality. Much of the reported evidence on risk reduction is from US and Scandinavian populations, where there are tangible WG dietary recommendations. Currently there is no quantity-specific WG dietary recommendation in the UK, instead we are advised to choose WG or higher fibre versions. Despite recognition of WG as an important component of a healthy diet, monitoring of WG intake in the UK has been poor, with the latest intake assessment from data collected in 2000/1 for adults and in 1997 for children. To update this information we examined WG intake in the NDNS rolling programme 2008-2011 after developing our database of WG food composition, a key resource in determining WG intake accurately. The results showed median WG intakes remain low in both adults and children and below that of countries with quantity-specific guidance. We also found a reduction in C-reactive protein concentrations and white blood cell counts with increased WG intake, although no association with other makers of cardio-metabolic health. The recent recommendations by the UK Scientific Advisory Committee on Nutrition to increase dietary fibre intake will require a greater emphasis on consuming more WG. Specific recommendations on WG intake in the UK are warranted as is the development of public health policy to promote consumption of these important foods.

What are whole grains and whole-grain foods?

Cereal grains, such as barley, corn, oats, rice, rye and wheat, are a staple food in the human diet and are important sources of dietary carbohydrate and protein. Whole-grain foods are foods made from cereals and flours which contain all three anatomical components of the grain - the outer bran, endosperm and germ. Although there is not one single definition of whole grains, similar definitions from the American Association of Cereal Chemists (AACC) International and the Healthgrain forum, a European consortium of scientists and industrial partners, are widely used. These definitions state that whole grains must contain the three component parts of the grain in the same relative proportions found in the intact kernel ⁽¹⁾. Additionally, the Healthgrain forum definition allows for small component losses due to processing of the grain ⁽²⁾. Other definitions found in country-specific reports are very similar to these ^(3,4,5) giving a general consensus on what constitutes a whole grain. As such, products that state 'whole grain', 'wholegrain' or 'whole' followed by the type of cereal or pseudo-cereal (named so because their composition is similar to that of cereal grains) in the ingredients list should comply with the consensus whole grain definitions and can be recognised as whole-grain foods. Similarly the term 'wholemeal', a regulated term for breads and flours in the UK ⁽⁶⁾, has requirements that align with whole grain definitions. Some cereal and pseudo-cereal ingredients, such as oats, oatmeal, brown rice, buckwheat and quinoa, often do not carry the 'whole'/'wholegrain' prefix. However, in the case of oats the largest majority is consumed as a 'whole grain' since oats are rarely refined to separate the bran and endosperm. Brown rice is so called because the bran is retained. The small seeds of most pseudo-cereals precludes refining ^(7,8). Currently there is no legal definition of a whole-grain food except for some specific in-country recommendations. For example, in the US foods must contain at least 51% whole grain by weight per reference amount customarily consumed to comply with a whole grain health claim. In Denmark flours, grains and rice must contain 100% whole grain, breakfast cereals 60% and bread 50% whole grain and in Germany pasta must contain 100% whole grain whereas wheat and rye breads must contain 90% whole grain.

Health benefits of whole grains- observational evidence

Cardiovascular diseases, type 2 diabetes, obesity and cancer are the most prevalent non-communicable diseases across the world ⁽⁹⁾. Cardiovascular diseases (diseases of the heart or blood vessels such as coronary heart disease) are the number one cause of death globally (31% in 2012 ⁽⁹⁾) and are currently the second biggest killer in the UK, after cancer ⁽¹⁰⁾.

Observational epidemiology studies suggest there is an inverse association between increased habitual whole grain intake and reduced risk of non-communicable disease. Results of systematic reviews and meta-analyses suggest there is a 20-30% risk reduction of cardiovascular diseases and type 2 diabetes, comparing low or non-consumers with whole grain intakes of 48-80g/d^(11,12). These reported associations may also be dose-responder with meta-analyses suggesting 22% cardiovascular disease risk reduction by increasing whole-grain food intake to 90g/d (i.e. 3 daily servings of foods containing whole grain) and an absolute risk reduction of 0.3% in type 2 diabetes rate for each 10g/d of whole grain consumed^(13,14). Increased whole grain intakes have also been associated with reduced risks of cancer, particularly colorectal cancers where a 10% relative risk reduction was estimated for an increment of 3 daily whole-grain food servings⁽¹⁵⁾. Furthermore high vs low whole grain intakes have been associated with reduced risks of digestive tract cancers as well as breast, prostate and pancreatic cancers^(16,17,18). One of the major risk factors for cardiovascular diseases, type 2 diabetes and cancer is obesity, which has become a global health concern as the rate has more than doubled since the 1980s⁽¹⁹⁾. Intake of whole grains may have a beneficial role in weight management or maintenance⁽²⁰⁾. A meta-analysis of 3 prospective cohort studies with a total of 119,054 participants, concluded that 3-5 daily servings of whole grains was associated with consistently less weight gained during 8-13 years of follow-up, compared with never/rare consumers⁽¹²⁾. These 3 cohort studies were conducted in US populations and the data are supported by a recent examination of trends in national data over 12 years which confirmed that whole-grain foods may contribute to weight management⁽²¹⁾. Most recently, meta-analyses have focused on investigating whole grain consumption in relation to mortality from non-communicable diseases, with similar results to the non-communicable disease risks⁽²²⁾. All-cause mortality and disease-specific (cardiovascular diseases or events, diabetes, cancers and respiratory disease) mortality risks are shown to be reduced by 5-30% for a doubling of whole-grain food intake as well as per 16g/d and 3 daily servings of whole grain^(23,24,25,26).

Many of the observational studies included in the systematic reviews and meta-analyses adjust their risk estimations for confounding factors which may also explain the suggested associations. Age, sex, smoking, physical activity, body mass, history of health, health markers and other dietary intakes such as energy intake, have all been considered and included in multivariable analyses. Varying effects of confounding are seen, for example an age and sex adjusted hazard ratio of 0.61 (95%CI 0.59 – 0.62) was attenuated to 0.77 (95%CI 0.75 – 0.79) after adjustment for smoking and further attenuated to 0.83 (95%CI 0.81 – 0.86) after additional

adjustments for race/ethnicity, alcohol intake, education, marital status, health status, obesity, physical activity, red meat, fruit, vegetable and total energy intakes and hormone use ⁽²²⁾. These results show that there is evidence of confounding, but the reported significant 17% reduction in all-cause mortality hazard ratio, for the highest whole grain consumers compared with the lowest, appears to be independent of the confounders tested. Although this study, and the majority of the observational studies, consistently report independent inverse associations even after adjustment for relevant confounding factors, it is important to note that the potential for residual confounding may still remain. In addition the majority of the studies included in the meta-analyses come from US and Scandinavian populations with a small number of studies from European cohorts and a very few from middle or far-Eastern population. Therefore, the applicability of the findings to populations with differing dietary patterns and cultural habits should be further investigated.

Health benefits of whole grains - intervention evidence

The results of intervention studies do not consistently corroborate the findings from observational studies. Some interventions show beneficial effects of consuming whole grains on health markers, whereas others fail to find significant results. For example, obese participants with metabolic syndrome who were given a 12 week dietary advice intervention to obtain all grain servings from whole grains, showed a reduction in plasma C-reactive protein concentrations and percentage body fat in the abdominal region compared with a whole grain avoidance group (refined grain group). In another randomised controlled trial, markers of inflammation were reduced in overweight and obese but otherwise healthy participants, with suboptimal diets, following a whole-grain wheat intervention vs a refined grain control group for 8 weeks. However, no significant variations in body composition, plasma lipids or glycemia were found in these participants or between intervention and the refined grain control ⁽²⁷⁾. Similarly, in a 16 week whole grain intervention, no changes in cardiovascular disease markers between intervention groups and controls were seen ⁽²⁸⁾. A meta-analysis of randomized controlled whole grain intervention studies on body weight and body composition concluded that the trials did not support the role of whole grain in body weight management. However, beneficial effects of whole grain on body weight may be more apparent for body fat percentage or abdominal adiposity which may be mediated through decreased inflammatory responses ⁽²⁹⁾. Explanation for the differing findings of interventions studies to those of observation studies are thought to be due mainly to the differences in study design. Intervention studies are time-restricted with no reported trial lasting longer than 4 months which may not be long enough

for sustained health benefits to be seen. Sample sizes are often small, although usually authors claim that they are powered to be able to detect any significant meaningful changes in disease markers resulting from the intervention. The type, variety and quantity of whole grains used in intervention studies differ and this may be another reason for inconsistent results. Some whole grains, such as oats, rye and barley, contain higher fibre, particularly soluble fibre, than wheat and rice. Therefore, the physiological effects on the body may differ between grain types and if one grain type or a mix of grains are included in the diet.

The outcomes of intervention studies are reported as the outcome on risk markers for disease, not the occurrence of a disease as this would not be possible within the time-frame of an intervention study. Therefore, comparison with observational studies where a particular disease or event has occurred may not be appropriate. Interestingly observational studies that report on markers for disease risk also have varying results ⁽³⁰⁾. For example in our recent analysis of UK whole grain intakes, no significant differences or trends in blood pressure, blood lipids or anthropometric measures between non-consumers and increasing tertile of whole grain intake were observed. However, a reduction in white blood cell counts by increasing tertile of whole grain intake, and a difference in adults with a small intake of whole grain compared with non-consumers was seen in C-reactive protein concentrations ⁽³¹⁾. This suggests that intervention studies and observational studies which report biomarkers of disease risk are more aligned in the inconsistency of their results compared with those that only report disease outcomes. Finally, intervention studies that report no changes in disease markers are most often carried out in healthy or overweight but otherwise ‘healthy’ volunteers. This raises the question, whether improvement in disease risk markers should be expected if the participants are otherwise healthy. Some of the largest effects are seen in intervention studies with ‘at risk’ participants with dyslipidaemia or obesity. Furthermore, it is known that as we age our health and health markers in general decline. We should re-consider the pharmacological paradigm which suggests that short-term dietary intervention with whole grains should improve or reduce disease risk in favour of a longer-term model which suggests that increased whole grain intake in the longer-term reduces age-related declines in health.

Despite the inconsistent results from whole grain interventions, to our knowledge, no study has shown or reported negative effects or outcomes of increasing whole grain intake on health markers. Therefore, advice to consume more whole grains could be a low risk public health strategy. Of course it is important to note that for a small proportion of the population with a gluten intolerance, caution must be made when consuming whole grains containing gluten.

However, gluten free whole grain alternatives such as amaranth, brown rice, buckwheat and quinoa are available and their consumption by those with gluten intolerance can be encouraged. Whole grain oats do not contain gluten but are sometimes cross-contaminated with wheat during harvesting or factory processing. Thus consumers should always check product labels for gluten-free oat ingredients for clarification.

Health benefits of whole grains – mechanisms of action

There is no one clear mechanism identified for which whole grains benefit the body, instead there are a combination of several processes suggested which may also interact with one another. Essentially the accepted pathways in which whole grains have an effect on chronic diseases can be split into two; dietary fibre and bioactive components (figure 1).

Whole grains contain cereal fibre and have increased amounts compared with refined grain counterparts. For example the Association of Official Analytical Chemists (AOAC) dietary fibre content of wholemeal bread is more than twice as high at 7g per 100g whereas for white bread it is 2.9g per 100g ⁽³²⁾. Insoluble and soluble dietary fibre improves digestive health through a range of effects such as stool bulking, altered intestinal transit time as well as increased colonic fermentation which induces the production of short chain fatty acids ⁽³³⁾. Beta-glucan, a soluble fibre found in higher concentrations in oats and barley, has been shown to lower blood cholesterol concentrations and improve post prandial insulin and glucose responses ^(34,35). In addition, these physiological effects of both soluble and insoluble fibre may also have satiating effects on appetite which may have a role in weight management ⁽³⁶⁾. Cereal fibre, in particular, has been highlighted as one fibre source that may reduce coronary heart disease risk ⁽³⁷⁾, and the need for trials investigating the effects of cereal fibre on type two diabetes risk has been emphasised ⁽³⁸⁾. It is also important to consider that the associated benefits of whole grains are above and beyond those of just the cereal fibre. Whole grains also contain a large amount of bioactive components such as phenolic acids, lignans, plant sterols, tocopherols, benzoxazinoids and alkylresorcinols as well as a variety of vitamins and minerals ^(39,40). Many of these have anti-oxidant and anti-inflammatory properties as well as providing essential nutrients into the diet of whole grain consumers which could lead to protection from later disease ^(41,42,43). New and emerging research into the gut microbiome suggests that whole grains may influence the type of bacteria that make up the gut microbiota which has beneficial effects on the host gut health ^(44,45,46). In a human trial it was shown that a mixture of whole grain types, a combination of whole grain barley and brown rice, increased gut microbial

diversity which induced some beneficial changes on the profile of bacterial populations in the host; evidence that in the short term, increased intake from a mixture of whole grains alters the gut environment and results in improvements in systematic inflammation ⁽⁴⁷⁾.

Whole grain intake recommendations

There are currently some recommendations to consume whole grains across the globe. These vary by country with some offering generic advice and others, which give merit to the observational evidence, providing quantity-specific daily target intakes ⁽⁴⁸⁾. For example in the US and Canada advice to “*make one-half of your grains whole grains*” is followed by a quantity recommendation of a minimum 3-5 ounce-equivalents (servings) per day (48-80g/d) ⁽⁴⁹⁾. Similarly quantity-specific dietary guidance is given in Denmark, however with a higher target to consume 75g/d whole grain per 10MJ/2400kcal diet (4 portions a day). Semi-quantity specific intake targets are advised in Singapore where advice for adults is to consume sufficient amount of grains, especially whole grains with at least one serving of rice and alternatives from whole-grain foods ⁽⁵⁾. In the UK, generic advice in the Eatwell Guide, is to “*choose wholegrain or higher fibre versions with less added fat, salt and sugar*”. In the majority of other countries with food-based dietary public guidance (including Australia, China, France, Germany and Ireland) generic advice to choose or include whole grain and consume more whole grain is given ^(11,48). The variety of whole grain recommendations across many countries could be confusing, particularly where quantity-specifics do not match. Target intakes are largely based on dietary fibre and endorsing whole grains as a source of fibre. Clearly targets need to reflect country specific cultural and traditional diets, however some consistency between countries based on scientific evidence would be useful.

Current whole grain intake

As with whole grain recommendations, whole grain intake varies across countries. Assessing intake of whole grains is challenging. Along with the universal issues of dietary intake reporting from either food frequency questionnaire or diet records, further difficulties arise for whole grains since the identification of these partly rely on participant knowledge, manufacturer information and standardised databases on the content of whole grains in foods. Such databases are publically available in the US through the United States Department of Agriculture (USDA) Patterns Equivalents Database ⁽⁵⁰⁾ and recently updated data have been published for whole-grain foods consumed in Australia ⁽⁵¹⁾. We have recently published our database of whole-grain foods consumed in the UK covering the period 1986-2016 ⁽⁵²⁾. Despite

the difficulties in assessing and measuring whole grain intake, the available data show that consumption and intake of whole grains in the majority of countries is low (Table 1). Average whole grain intakes for adults range from as little as 4g/d in Italy, measured in 2005-06, and 5g/d in France measured in 2009-10, to as high as 58g/d (63g/d/10MJ) in Denmark measured in 2011-13^(53,54,55). The higher reported whole grain intakes in the Danish population are attributed to a combination of traditional diets that include whole-grain foods, such as rye bread, and the recent success of the Danish whole-grain campaign⁽⁵⁶⁾. The campaign, a public and private company partnership, aiming to increase accessibility and awareness of whole grains and the associated health benefits, has seen an increase in average Danish intakes of 75% from 2004-2013. In the UK whole grain intake from foods with at least 10% whole grain content was reported to be 7g/d for children and 14g/d for adults from the 2000-01 and 1997 national dietary survey, respectively^(57,58). We (the authors) have worked to update these data using the UK National Diet and Nutrition Survey data from 2008-11, covering the first three years that the survey has been run on a rolling programme basis. We reported average whole grain intakes of 20g/d and 13g/d in adults and children, a slight increase on the previous survey⁽⁵⁹⁾. Although, our assessment included food with any whole grain content we found very minimal differences when assessing intakes only from foods with at least 10% whole grain content. As such we concluded that whole grain intakes in the UK remain low, particularly in teenagers and younger adults as well as for those with lower socioeconomic status. To investigate any potential health benefit of higher whole grain consumption, we split the whole grain consumers into tertiles of intake and compared health marker levels between the three groups and non-consumers. As previously mentioned, no significant association was found between higher whole grain intakes and measures of body composition or blood pressure, which may have been due to the small variability in the population and overall low level of whole grain intake. Only 17% of adults consumed at least 48g/d or more whole grain, the current US intake recommendation and the amount suggested to be associated with reduced disease risks. We found that whole grain intake came mainly from breads and ready-to-eat breakfast cereals, but we noted very small intakes from pasta. However, 'white bread' and 'pasta, rice, pizza and other miscellaneous cereals' were the two most commonly consumed cereals and cereal products, eaten by more than 70% of the total population⁽⁶⁰⁾. This gives opportunity for replacement of refined grain breads and pastas with whole grain varieties and the potential to increase population whole grain intakes. In particular, increased consumption of whole grains provides opportunity to increase dietary fibre intakes since our analysis showed

that dietary fibre intakes were 5g/d and 3g/d significantly higher in adult and child whole grain consumers compared with non-consumers.

Barriers to new whole grain intake recommendations

Although the new Eatwell Guide and advice from Public Health England has raised the profile of whole-grain foods⁽⁶¹⁾, we believe that a more explicit recommendation is required. We also suggest that a global recommendation would be useful to improve clarity and encourage industry to develop more whole-grain products. However, before any new recommendation can be made consideration is needed of potential difficulties that may arise. Consumer desirability of whole grains, particularly in the taste, texture, price and availability will be key factors in aiding an increase in whole grain intakes. The availability of whole-grain food products has increased as has the popularity of foods perceived as being more healthy⁽⁶²⁾. However, as a consequence in some cases these foods can be more expensive⁽⁶³⁾. Food manufacturers should seek opportunities to develop new whole-grain foods which are appealing and affordable for the consumer. Manufacturers must be allowed to label their foods effectively and in a way which is regulated for the consumer. This is linked to a second potential barrier to a quantity-specific whole grain recommendation which is to have a clear definition of a whole-grain food. As part of our work on updating national intake data in the UK we have developed a database of the whole grain contents of foods consumed from several UK surveys⁽⁵²⁾. Following the guidelines by Ross *et al.*⁽⁶⁴⁾ we report on a dry weight basis from which intakes can be calculated in grams per day given the portion size consumed. The database also contains whole-grain foods as single raw ingredients as well as on an as consumed basis so that intake can be calculated either from recipe ingredients with weights or as the food as eaten. For example the whole grain content of dry wholemeal pasta is estimated to be 89.5% dry matter whereas wholemeal pasta boiled is estimated to be 30.9% whole grain dry matter as eaten. This database, as with other databases, highlights the differing amounts of whole grain contained in food products. In the US the health claim “*Diets rich in wholegrain foods and other plant foods, and low in saturated fat and cholesterol may help reduce the risk of heart disease*” is allowed for use only on foods that contain at least 51% whole grain^(65,66). Previously in 2002 the UK also had a health claim that was allowed for the use on foods containing at least 51% whole grain. “*People with a healthy heart tend to eat more whole-grain foods as part of a healthy lifestyle*”⁽⁶⁷⁾. However, this claim is no longer permitted for use, since in 2010, the European Foods Standard Agency rejected the use of all whole grain health claims in Europe on the basis that whole grain was “*insufficiently characterised*”⁽⁶⁸⁾. More recently the US AACC

International and a multidisciplinary expert roundtable have proposed a characterisation that whole-grains foods must deliver at least 8g whole grain per 30g serving (~27% whole grain content) ^(11,69). The Healthgrain forum have recently proposed that a whole-grain food should contain at least 30% whole grain content on a dry matter basis with more whole-grain ingredients than refined grain ingredients in the final product. This is in addition to compliance with country-specific fat, salt and sugar limitations⁽⁷⁰⁾. A scientific consensus and subsequent studies using one definition of a whole-grain food would add to the evidence concerning health benefits of whole grains and aid public bodies in recommending food-based whole grain guidance.

Concluding remarks

The observational evidence on the long term health benefits of higher whole grain consumption is clear and consistent. As a result some public health groups advise quantity-specific daily whole grain intake recommendations. Since grains are important dietary sources of energy and other nutrients including dietary fibre, and whole grain varieties contain higher amounts of fibre compared with refined grain varieties, recommendation to consume them should be emphasised. The current UK advice from the Eatwell Guide, now includes images of whole-grain foods and the emphasis on choosing ‘*wholegrain and higher fibre versions with small amounts of salt fat and sugar*’ ⁽⁶¹⁾ The inclusion of whole-grain food images within the ‘carbohydrates’ section of the plate is a step in the right direction. The recent Scientific Advisory Committee on Nutrition (SACN) Report on Carbohydrates and Health, has advised that dietary fibre intakes should be raised to a minimum of 30g/d for adults and 15-25g/d for children with no more than 5% of dietary energy coming from free sugars ⁽⁷¹⁾. We believe that a quantity-specific recommendation for whole grain intake would be more helpful to the general public than the general statement in the Eatwell Guide since 30g/d fibre will be impossible to achieve without the inclusion of whole grains. For example, the British Nutrition Foundation (BNF) have developed a 7-day meal plan which is designed to indicate the amount of different foods needed to achieve the fibre and free sugars targets ⁽⁷²⁾. Within this meal plan more than half of the carbohydrate-rich foods are whole-grain foods. In order to achieve 30g/d of dietary fibre an adult would need to consume almost 6 servings a day of whole grain, in addition to over 8 portions of fruit and vegetables a day (Table 2). This gives a very clear indication of the need to consume substantial quantities of whole grain, in addition to fruit, vegetables together with high-fibre beans and pulses which are also included in the meal plan.

Increasing whole grain intakes may be difficult. Studies in the US, have shown that despite having a quantity-specific recommendation of 3oz-equivalents per day, this target has not been achieved. Assessing trends across 12 years of the National Health and Nutrition Examination Survey showed that, although recommended intakes of total grains are being met, only small increases in whole grain intake were observed and less than 10% of Americans currently meet the recommendation for whole grain intakes. This suggests that despite the increasing consumer interest and availability of whole-grain foods, little progress in replacing intake of refined grains with whole grains has occurred in the past 12 years ⁽²¹⁾. In contrast, as previously mentioned, the Danish population has shown considerable success in improving whole grain intakes, demonstrating that with public and private partnership campaigns population dietary habits can change.

It is important that any new dietary recommendations focus on replacement of refined grain foods with whole-grain foods so that overall energy intake does not increase. Finally, there may be potential for co-ordinating a whole-grain recommendation with the current UK fruit and vegetable guidance. For example, the current ‘5-a-day’ campaign for portions of fruit and vegetables could be mirrored by a ‘3-a-day’ campaign for whole grain. This would require clarity in definitions of whole grain, whole-grain foods and mechanisms to enable consumers to identify portions of whole-grain foods.

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385 *Authorship*

386 KDM collated the evidence, analysed UK data, gave the presentation at the Nutrition Society's
387 Summer Meeting and drafted the article. CJS supervised the research, contributed to writing
388 and critical review of the manuscript. MSP supervised the research and critically revised the
389 manuscript for intellectual content.

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582

583 Table 1 Whole grain intakes of adults in national surveys

Country ; Study	Age range (n)	Whole grain intake (g/d unless otherwise stated)			
		Mean (SD/SE)	Median (5 th - 95 th percentile)	% non-consumers	% meet target intake (target)
Italy; <i>INRAN-SCAI (Italian food consumption database) 2005-06</i> ⁽⁵³⁾	18 - 65 years (TP:2313, M:1068, F:1245)	TP: 4 (12) M: 3 (12) F: 5 (13)	TP: 0 (34*) M: 0 (30*) F: 0 (38*)	TP: 76% M: 84% F: 69%	1% (48g/d)
France; <i>Comportements et Consommations Alimentaires en France 2010 Survey</i> ⁽⁵⁴⁾	18+ years (TP:1389, M:588, F:801)	TP: 5 (0.3) M: 4 (0.5) F: 5 (0.5)	TP: 0 (26†) M: 0 (25†) F: 0 (27†)	TP: 68% M: 72% F: 63%	7% (48g/d)
UK; <i>National Diet and Nutrition Survey 2000-01</i> ⁽⁵⁸⁾	19 - 64 years (TP:1692, M:758, F:934)	TP: 23 (28)	TP: 14 (0 – 98)	TP: 29% M: 31% F: 27%	16% (48g/d)
UK; <i>National Diet and Nutrition Survey 2008-11</i> ⁽⁵⁹⁾	19+ years (TP:1491, M:691, F:880)	TP: 26 (28) M: 29 (31) F: 24 (23)	TP: 20 (0 – 80) M: 20 (0 – 96) F: 19 (0 – 67)	TP: 18% M: 21% F: 15%	17% (48g/d)
USA; <i>National Health and Nutrition Examination Survey 2011-12</i> ⁽²¹⁾	19+ years (TP:4878)	TP: 0.97 (0.05) oz eq/d‡	-	TP: 46%	8% (3 oz eq/d‡)
Singapore; <i>National Nutrition Survey 2010</i> ⁽⁷³⁾	18 - 69 years (TP:739, M:377, F:368)	TP: 26 (-) M: 22 (-) F: 31 (-)	-	-	27% (1 serve)
Australia; <i>Australian Grain and Legumes Consumption and Attitudinal Study 2014</i> ⁽⁷⁴⁾	2 - 70 years (TP:3031, M:1194, F:1837)	TP: 28 (-)	-	TP: 25%	Adults only: 30% (3 serves/d ~48g/d)
Ireland; <i>National Adult Nutrition Survey 2008-10</i> ⁽⁷⁵⁾	18 - 90 years (TP:1051, M:523, F:528)	TP: 29 (37) M: 33 (45) F: 26 (27)	-	TP: 20% M: 21% F: 19%	21% (48g/d)
Norway; <i>Norwegian Women and Cancer Cohort 1992-98</i> ⁽⁷⁶⁾	30 - 60 years (F:1797)	F: 51 (36)	F: 44 (0 – 120)	F: ~5%	F: 35% (75g/d/10MJ)
Sweden; <i>Northern Sweden Health and Disease Study Cohort 1992-98</i> ⁽⁷⁶⁾	30 - 60 years (TP:2989, M:1372, F:1617)	M: 58 (50) F: 41 (32)	M: 49 (0 – 149) F: 35 (0 – 102)	TP: ~5%	M: 29%, F: 27% (75g/d/10MJ)
Denmark; <i>Danish National Survey of Diet and Physical Activity 2011-13</i> ⁽⁵⁵⁾	15 - 75 years (TP:3189, M:1546, F:1643)	TP: 58 (-) M: 65 (-) F: 51 (-)	-	TP: 0%	30% (75g/d/10MJ)

584 SE: Standard Error; SD: Standard Deviation; TP: Total population; M: Male; F: Female;

585 *Median and 97.5th percentile; †Median and 95th percentile; ‡ ounce-equivalents (one oz eq can be either 16g

586 or 28.35g depending on the food source hence is not converted in grams⁽²¹⁾).

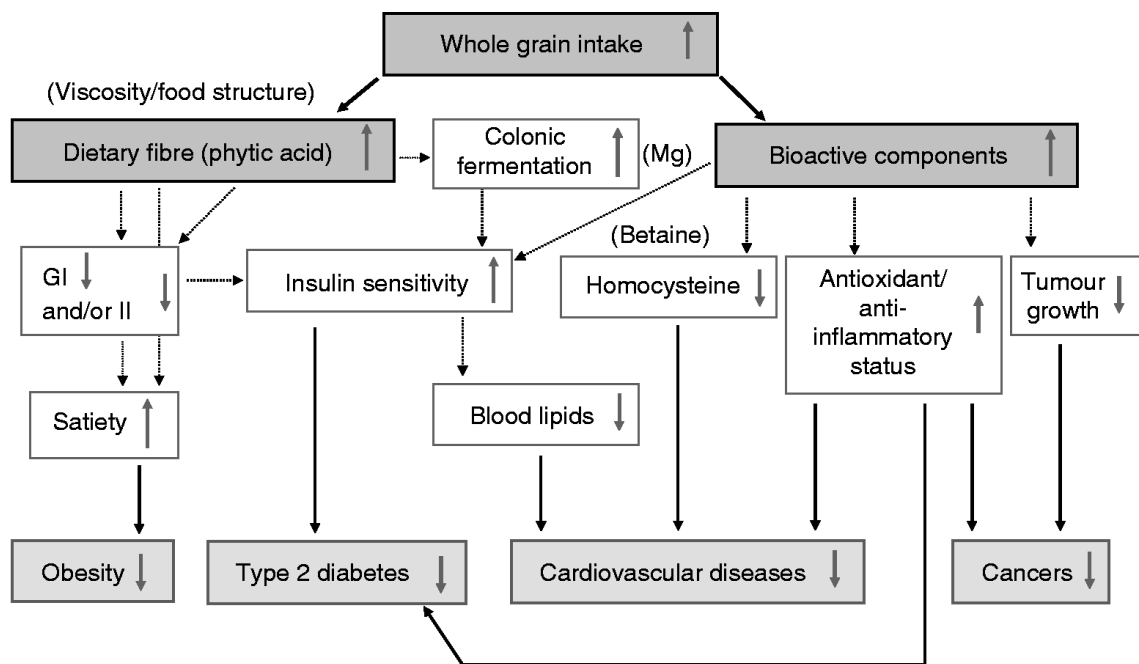
587 Table 2 Estimated whole grain servings based on a sample meal plan to achieve the new fibre
588 and free sugars recommendations

Meal plan day	Whole-grain food (portion*)	Estimated whole grain servings†	Fruit and vegetable portions ⁽⁷²⁾
Monday	Muesli (50g) 2 Oatcakes (26g) Brown rice (180g) Wholemeal pitta (47.5g)	9.1	9.9
Tuesday	Wholewheat pasta (230g) 2 Chocolate digestive biscuits (36g)	7.5	7.8
Wednesday	2 fortified wheat biscuits (40g) Brown rice (180g)	5.8	9.5
Thursday	Wholegrain toast (31g) 2 slices wholewheat bread (72g)	3.7	7.1
Friday	2 fortified wheat biscuits (40g) Wholemeal wrap (70g)	4.9	6.2
Saturday	2 slices wholemeal toast (62g) Wholewheat spaghetti (220g) Flapjack slice (70g)	9.4	10.4
Sunday	Porridge (160g)	1.1	7.8
Total <i>per week</i>		41.6	58.6
<i>per day</i>		5.9	8.4

589 *portion sizes from Food Standards Agency⁽⁷⁷⁾

590 † 16g whole grain per serve

591 Figure 1: Accepted mechanisms for effects of whole grain on chronic disease⁽⁴³⁾.



592
593 Figure Legend

594 Fardet ⁽⁴³⁾ : Current accepted mechanisms for how whole grain protects against major chronic diseases.

595 GI, glycaemic index; II, insulinaemic index.